The roles of experience, commitment to new platforms, and inter-firm cooperation in shaping new product performance

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CHAPTER 2. Fast or Slow Renewal: The Role of Depth and Breadth of Experience in Shaping the NPD Performance after the Technological Change

Abstract: Technological developments pose existential challenges to firms especially when the technological challenges are radical as opposed to incremental. This study investigates how firms' previous product development efforts, that have led to a *depth* and *breadth* of relevant experience, determine future New Product Development performance. Past experience can either be deep (for a same technology) or broad (with different generations of technologies). We measure NPD performance in terms of new product quality. We argue and show that the degree to which firms' experience translates into high quality products depends on the time firms take to develop new products (a time-release strategy). Analyzing 940 PC video games developed by 378 video game developers in the 1995-2014 period we find that the radicalness of a newly developed game platform impacts the effects found.

2.1. Introduction

Industries are often confronted with exogenous innovations or technological changes that shift competition (Henkel et al., 2015; Prencipe and Tell, 2001; Utterback, 1996). To remain competitive in such environments, firms have to adjust themselves to new emerging demands, update their routines, and, if needed, set up new product development procedures (Huizingh, 2017; Kaplan and Tripsas, 2008). By doing this, firms gain new product development (NPD) experience that might be useful for the development of the next generation of products. In particular, NPD experience helps to improve firms' performance by advancing its learning process (Caner and Tyler, 2014; Eggers and Park, 2018; Li et al., 2013; Prencipe and Tell, 2001).

Researchers distinguish two types of learning outcomes depending on the radicalness of developed products or technologies used in products (Eisenhardt and Martin, 2000; Pavlou and El Sawy, 2011). When firms develop new products based on incremental technologies, such entities advance their incremental knowledge and increase performance of their core technologies by means of improving intra-organizational processes (Robertson et al., 2012; Teece et al., 1997). When firms develop new products based on radical technologies, they gain knowledge about new technologies, create new value propositions, master new ways of production, and build expertise in changing intra-organizational processes (Dahlin and Behrens, 2005; Eisenhardt and Martin, 2000). Hence, by incorporating incremental and radical technological changes firms enrich two different dimensions of their NPD experience: *depth of experience*, reflecting the extent of exploitation of the same technology, and *breadth of experience*, indicating the extent of exploration of different generations of a technology.

Existing studies provide mixed findings about the relationship between NPD experience and performance (Eggers and Park, 2018). The following two prominent streams can be distinguished: (1) the NPD literature that sheds light on how firms learn from their own NPD experiences (inside-out) (Argote and Miron-Spektor, 2011; Cohen and Levinthal,1990; Levitt and March, 1988), and (2) the organizational learning literature that analyzes how firms learn from (adjusting to) changes happening in the industry (outside-in) (Frank et al., 2016; Nemet, 2009; Tsang, 1997). Despite conceptual differences, both streams of the literature indicate that the learning and gaining experience process may vary depending on the type of technology (radical or incremental). The NPD literature suggests that firms learn and improve their abilities from continuous development of new products, and that their NPD experience yields different learning effects in terms of depth and breadth of knowledge (Caner and Tyler, 2014; Katila and Ahuja, 2002). According to the organizational learning theory, firms cope with radically or incrementally changing environmental settings (Eisenhardt and Martin, 2000; Malerba, 2002;

Pavlou and El Sawy, 2011) and learn yet differently from the interaction with such exogenous changes (Argote, 1999; Crossan et al., 1999). The both streams of the literature provide a common understanding of the dual nature (radical or incremental) of firms' NPD experience, knowledge and technological environment in which firms operate. Therefore, rather than relying on one of these theoretical approaches as most studies do (Bingham and Davis, 2012), our study incorporates both perspectives and analyzes how different types of NPD experience (depth and breadth) influence new product quality in the presence of radical and incremental technological changes.

Although NPD experience is a crucial intangible asset that influences several characteristics of the new product including its quality (Argote and Miron-Spektor, 2011; Eggers and Park, 2018), it does not bring much without taking into account the timing of the introduction of a new technology in the production process (Afuah, 2004; Lieberman and Montgomery, 1988; Rasmusen, and Yoon, 2012). When a new technology emerges, firms face the dilemma to either (a) quickly adopt and master the new technology to attain first-mover advantages, or (b) wait and learn from competitors until the new technology is well established so that all negative effects related to its quick adoption are absorbed by other firms (Rasmusen and Yoon, 2012; Rodríguez-Pinto et al., 2011), or (c) decide not to adopt the new technology and continue developing new products by relying on the prior technology. Such a dilemma regarding the speed of adoption of the new technology make us to consider another time-related stream of academic literature.

This study connects insights from the organizational learning and NPD literature (Caner and Tyler, 2014; Katila and Ahuja, 2002; Pavlou and El Sawy, 2011) to the first-mover (dis)advantage literature (Fisch and Ross, 2014; Lieberman and Montgomery, 1988; Peres et al., 2010). In particular, we consider how firms (1) learn from the interaction with different technological regimes, (2) use the resulting depth and breadth of experiences to proxy firms' ability to acquire and improve knowledge on internalizing this knowledge in new product development (NPD) and finally, (3) link such learning effects to the time-release strategy. The interplay of these three elements contributes to our understanding of the relationship between NPD experience and NPD performance. As a setting for our study we select the PC video game industry where new products (i.e., video games) are frequently released in the context when firms are confronted with a continuous flow of technological advancements, such as sophistication of hardware components and programming techniques affecting the development of video games and firms' routines.

This study extends the literature on NPD experience and knowledge-based view in the following ways. First, we focus the research directly on NPD experience (depth and breadth) rather than on NPD related knowledge as most studies do (Eggers, 2012; Forés and Camisón, 2016; Katila and Ahuja, 2002). Differently to NPD related knowledge that can be considered as a portfolio of within-industry (depth) knowledge or outside-industry (breadth) knowledge, NPD experience (depth and breadth) is considered as a continuously changing asset that is acquired over time. The study shows that breadth and depth of experience positively influence new product performance but depth of experience devaluates faster than breadth of experience. In addition, our research shows that the impact of these two types of NPD experience is not unidimensional and depends on the time-release strategy. Lessons learned from depth of experience improve new product quality only for the incremental technological regime, but no direct effects of breadth of experience exist for either incremental or radical technological regimes. The effect of breadth of experience is only visible when time-release strategy is taken into account. This fact leads us to the second contribution where we show that both effects of depth and breadth of experience are contingent on the firm's time-release strategy and radicalness of technological regime changes. The positive impact of depth of experience is enhanced when firms develop and release products more quickly. The positive impact of breadth of experience is enhanced when firms face incremental and radical technological regime changes but only when experienced firms take more time to develop and release products. These findings suggest that the impact of depth and breadth of experience differs due to external factors.

These results open a new avenue within NPD experience, NPD performance and knowledge-based literature (Felin and Hesterly, 2007; Forés and Camisón, 2016). The effects resulting from a complex interplay between NPD experience, a release timing and a technological regime change imply that it is incorrect to simply assume that both types of experience are beneficial for one certain technological regime. Our results suggest that NPD experience with radical changes (breadth) may also enhance some innovation-related activities that are beneficial when incremental changes occur. This again supports the distinctive learning effects that may be derived from the two types of NPD experience, and that they differently enhance firms' NPD capabilities.

This study contributes as well to the first-mover (dis)advantage or market-entry literature (Lieberman, 1989; Schilling, 2002; Suarez and Lanzolla, 2007). As knowledge acquisition or development requires time investments (Amir and Stepanova, 2006; Lieberman and Montgomery, 1988), and as the value of knowledge depreciates over time (Argote, 1999), we consider firms' time-release strategies to enhance our understanding of the NPD experience-performance link. In spite of the importance of the time aspect and its potential impact on the link between NPD experience and NPD performance constructs, this research perspective has not been yet explicitly addressed in the literature. In the context of radicalness of a technological change (regime) and types of NPD experience, it clearly shows under which circumstances a fast (or slow) time-release strategy of a new product becomes more beneficial. Another novelty of this study is the simultaneous inclusion of firms' time-release strategy and the types of NPD experience into the conceptual model. Most existing studies focus on the positive or negative effects of a fast/slow product release (technology adoption) on NPD performance, while this study elaborates on firms' NPD experience in terms of its breadth and depth dimensions that serve as predictors of positive or negative effects from the fast or slow time-release strategy.

The study is organized as follows: (1) a literature part that introduces the conceptual model; (2) a hypotheses elaboration part; 3) a discussion of the empirical setting, data analysis and results part and (4) a general discussion and conclusions part.

2.2. Conceptual Background

Over time, firms accumulate experience and knowledge[4] useful to develop new products and to improve their NPD performance. The development of products based on the same technology enriches firms' experience and deepens their knowledge in using the focal technology (Teece et al., 1997). Many industries, however, are characterized by technological changes, which might be sometimes incremental and sometimes radical. Technological platforms or standards cyclically substitute each other (Anderson and Tushman, 1990; Foster, 1986; Gawer, 2014). When a new technology challenges the dominant technology, firms are forced to decide whether to explore and to exploit this new technology or not (Agarwal and Helfat, 2009; Klarner and Raisch, 2013; Lavie, 2006). What knowledge firms have accumulated in the past may or may not turn out to be useful under the new circumstances. This study helps to understand what type of knowledge (deep or broad), accumulated over time by a firm, and under which circumstances (incremental or radical shift of a technology), will help them to perform better at NPD. We test the conceptual model presented in Figure 2, the rationale for which we develop below.

[4] Here we refer to knowledge as firm's theoretical or practical understanding of how to develop new products, and the ability (developed through training or experience) to do so.

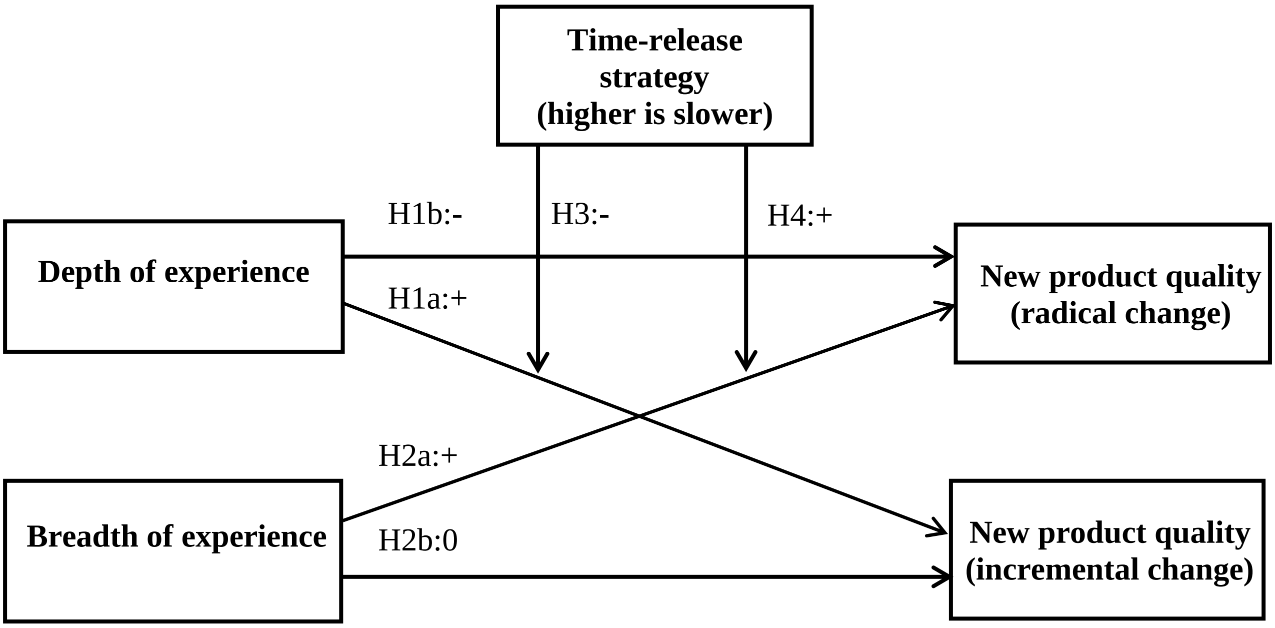

Figure 2. Conceptual model

In accordance with the distinction between exploitation and exploration (March, 1991), technologically unstable environments force firms to develop new and completely different capabilities (exploration); while technologically stable environments force firms to develop abilities that allow them to cope effectively with incremental technological changes (exploitation) (Helfat and Peteraf, 2003; Winter, 2003; Zahra et al., 2006). The existence of these two types of capabilities evidences two different sources of NPD experience accumulation.

The successful completion of repetitive exploration and exploitation cycles increases firms' NPD experience, which, in turn, improves the process of exploitive and explorative learning (Argote et al., 2003; Caner and Tyler, 2014; Eggers and Park, 2018; March, 1991). Applying Katila and Ahuja's (2002) dimensions of knowledge that reflect (1) the level of improvement of existing knowledge and (2) the scope of new knowledge exploration, we suggest to capture the dual nature of knowledge and consider NPD experience from two angles, namely depth and breadth of experience.

The market-entry literature highlights that the advantages of introducing new products are time-dependent (Higon, 2016; Lieberman and Montgomery, 1988, 1998; Min et al., 2006), and that the emergence of a new radical technology forces firms to define an appropriate time-release strategy for their new products (Kim and Lee, 2011; Lee, 2009; Markman et al., 2005). Given that experienced and inexperienced firms may benefit differently from the fast adoption of new technologies in NPD (Benner, 2007; Fisch and Ross, 2014; Rasmusen and Yoon, 2012), we also consider the impact of NPD experience on NPD performance through the prism of its interaction with the time-release strategy.

There are two other interactions that could be potentially influenced by the time-release strategy: (i) the one between depth of experience and new product performance, when firms encounter a radical change, and (2) the one between breadth of experience and new product performance, when firms encounter an incremental change. We do test the effects of these interactions and report the results in Table 3. However, we do not provide a conceptual grounding for them. The reason behind is that the direct effects of both depth and breadth of experience (conditioned by radical and incremental changes respectively) undermine the moderating effects of time-release strategy. We consider that depth of experience negatively affects new product performance when firms encounter a radical change. In this case, depth of experience does not provide abilities and knowledge that are required during such a change and firms that leverage on depth of experience lose in terms of new product performance. Our expectation is that time-release strategy will not impact the effect of depth of experience because firms will not be able to utilize knowledge from depth of experience in a way that requires a new technology. A similar logic applies to breadth of experience: we hypothesize a ‘no’ effect for breadth of experience when firms encounter an incremental change. Firms will not lose in new product performance since knowledge from breadth of experience is sufficient for producing products of expected market quality but they also will not improve new product quality because, for an incrementally changing technology, firms require knowledge acquired from routinised activities (depth of experience) rather than knowledge from breadth of experience. In this instance, time-release strategy will not alter the effect of breadth of experience.

2.3. Hypotheses

2.3.1. Depth of experience

Depth of experience accumulates when firms use the same technology for the development of new market offerings. A relatively stable technological environment characterized by incremental technological changes allows a firm both to use its existing body of knowledge, but also to enrich and deepen its knowledge and experience (Forés and Camisón, 2016; Klarner and Raisch, 2013; Polanyi, 1983). In technologically stable environments, firms can comprehensively exploit and master the same technological area, gaining improved understanding why and how something 'works', and being able to explore how relatively separated pieces of knowledge can be combined. In the absence of radical technological changes, firms are able to better understand and integrate the knowledge they developed or acquired over time (Cepeda and Vera, 2007), but also to integrate the knowledge developed or acquired possibly in separate departments in the same firm. Based on a relatively stable technology, firms can establish collaborative networks with other firms for knowledge exchange (Schrader, 1990; Tsai, 2009). Firms may also identify the weaknesses of their production processes and eliminate them via a repetitive use of the same technology (Teece et al., 1997); optimize prior routines (Argote, 1999; Wilden and Gudergan, 2015); thoroughly experiment with the technology (Fredrickson, 1984); improve existing products to the level of their maximum performance within the existing technological limits (Forés and Camisón, 2016; Winter, 2000); and better explore and understand consumer preferences (Kumar et al., 2011).

In contrast, in volatile technological environments characterized by radical technological changes, firms are limited in their ability to master one particular technology (Eisenhardt, 1989; Klarner and Raisch, 2013) and will need to invest resources in the highly risky exploration and eventual adoption of the radical technology (Levitt and March, 1988; Sharma et al., 2016). Existing studies suggest several reasons for a harmful effect of depth of experience on firms' NPD performance when the technological environment turns from being stable to volatile.

First, while gaining experience with and exploiting one focal technology, a firm may become inert to further technological exploration (Hannan and Freeman, 1984; Junni et al., 2013). This lock-in into a specific technological trajectory may become cumbersome (Zahra, 2010) when the technological environment loses its stability and becomes volatile. Firms that have accumulated considerable experience with a single technology may struggle to cope with the novel, complex and radically different knowledge that is part of the new radical technology; hence, such firms may suffer from their past experience, and introduce a new product that is inferior to those of their competitors.

Secondly, by being attached to the old technology and lacking knowledge about the new technology, firms may implicitly or explicitly use already established techniques and routines for mastering the new emerging technology (Betsch et al., 2004; Yang et al., 2014). If radical technological change occurs, the established routines and knowledge may become nontransferable. Firms might need to unlearn established practices in order to be able to develop new practices related to new technologies.

Thirdly, firms' extensive orientation on one technology makes them unable to identify needs of new customers (Christensen and Bower, 1996; Chuang et al., 2015) and unwilling to cannibalize current products for the sake of these underserved customers (Henderson and Clark, 1990; Rank et al., 2015). Extensive use of old technologies may limit firms' ability to enter and benefit from the newly developed markets created by radical technologies and constrain the development of products that have new functionalities. Hence, we hypothesize that:

Hypothesis 1. ***Depth*** *of experience (a)* ***positively*** *affects new product quality when firms are confronted with incremental technological changes, but (b)* ***negatively*** *when firms are confronted with radical technological changes.*

2.3.2. Breadth of experience

Persistence in adoption of new technologies fosters firms' ability to survive radical changes even in the short run (Eggers and Park, 2018; Eisenhardt and Martin, 2000). To survive a technological change, firms must learn how to re-build their internal routines and strategy that would allow decreasing the costs of transition from the old to a new technology (Klarner and Raisch, 2013; Teece et al., 1997). In particular, firms learn how to recognize the set of skills and assets required for the adoption of a new technology and how to (re-)allocate resources which are necessary for mastering such a technology. With the enrichment of NPD experience, firms develop the dynamic ability to establish new alliances for faster exploration and commercialization of new technologies (Rothaermel and Deeds, 2006; Teece et al., 1997). Such firms can use their previous NPD experience to re-orient the production process on emerging customers' needs (Zahra and George, 2002) and may be less afraid to unlearn existing knowledge, exit from obsolete or redundant routines and de-invest in currently valuable assets (Rodon and Zafarnejad, 2012). Accumulation of NPD experience with technological changes facilitates firms' abilities to better recognize threats and opportunities, which are brought by a new technology. This, in turn, makes them better prepared for future technological changes. We consider such NPD experience as breadth of experience. The presence of this type of experience evidences that firms are capable of successful adoption and incorporation of each subsequently emerging technology in the production process.

In incrementally changing technological environments, the usefulness of breadth of experience is limited. The major task of firms here is to improve existing routines and to optimize organizational and production processes (Zollo and Winter, 2002). In such environments, firms aim to implement more effective ways of production, distribution and promotion of their products; focusing strongly on optimization of the cost efficiency rather than on R&D (Eisenhardt and Martin, 2000). Lessons learned from surviving multiple radical technological changes might be less applicable for the stable environment compared to the volatile one, as it is well-known what domains of knowledge an incremental technological change will impact. Insights from other domains of knowledge are not nearly as likely to become relevant in such incremental circumstances (Hurmelinna-Laukkanen et al., 2008; Miller and Shamsie, 1996). Therefore, we hypothesize that in incrementally changing environments the breadth of experience will not be beneficial for new product quality. Based on this, we hypothesize that:

Hypothesis 2. ***Breadth*** *of experience (a) does* ***not*** *impact new product quality when firms are confronted with incremental technological changes, but (b)* ***positively*** *affects new product quality when firms are confronted with radical technological changes.*

2.3.3. Moderator: Time-release Strategy

Depth and breadth of experience are essential factors in predicting firms' NPD performance, but we argue here, the degree to which this NPD experience translates into the release of new high-quality products depends on the time-release strategy. The literature, not always focusing on the same performance outcome, is inconclusive about the moderating effect of the time-release strategies adopted by firms on their performance. Some studies argue that firms may disrupt the entire industry and thus capture a large market share in the longer term when they succeed to quickly adopt a radically new technology and release a product that makes use of it (Christensen, 1997; Christensen and Rosenbloom, 1995). First-movers, who exploit such a technology, may establish and maintain a technological advantage for a long period of time (Kerin et al., 1992). Other studies demonstrate that a prompt adoption of a new technology does not always bring benefits for the development of new superior products and, to the contrary, negatively affects firms' performance in terms of market share, positive economic profit, product quality, and ability to create disruptive technology (Cho et al., 1998; Kim and Lee, 2011; Lieberman and Montgomery, 1988; Rodríguez-Pinto et al., 2011; Sood and Tellis, 2011).

One of the main challenges for firms when a new technology emerges is the competition for the dominant design among different developers (Anderson and Tushman, 1990; Henderson and Clark, 1990; Peng and Liang, 2016; Srinivasan et al., 2006). The quick release of a new product on the market after a technological change can lead to a situation in which features in the product design are accepted broadly in the market as preferred features. A firm to first launch a new product with such features might have intellectual property rights in them, will have cost of production advantages and will be recognized by consumers more readily.

On the other hand, firms that quickly adopt the new radical technology will not necessarily win, and their failures (e.g., launching half-baked product innovations, misinvestments) provide valuable lessons for competitors who may adopt and exploit the new technology in a better way (Lieberman and Montgomery, 1998). Firms that do not immediately release products based on the new technology may learn from fast adopters and omit their mistakes. They also have more time to experiment and develop a more fine-tuned product design (Kim et al., 2016; Li et al., 2013; Suarez and Lanzolla, 2007). By saving on resources for market development, technological exploration and market intelligence (Carpenter and Nakamoto, 1989; Shankar et al., 1998), and learning from the experience of forerunners, such "belated" firms can more efficiently use their resources invested in NPD process, which, in turn, may positively impact new product quality.

We argue that one reason why the findings are inconclusive is that these studies focus on different outcome variables. The performance outcome we focus on here – New Product Quality – is one that facilitates studying the effect of the introduction of a new technology to determine which firms should be best positioned to deal with the new circumstances based on the experience (knowledge) that they have. We further argue, however, and provide empirical analysis for, that it matters crucially to a firm just how radical the new technology actually is: one should expect very different performance outcomes for firms facing radical as opposed to incremental technological changes.

We also argue that time-release strategy moderates the effect of firms' NPD experience on new product quality. We hypothesize that, when firms operate within incrementally changing technological environments, the positive effect of depth of experience may disappear if firms do not quickly release products based on the new technology. Extensive time spent on product development may harm new product quality (Argote, 1999) because firm's knowledge gained from accumulated NPD experience with the same technology quickly devalues over time (Argote, 1999). Therefore, firms can benefit from the acquired knowledge when they quickly exploit it, and put it into use (Argote, 1999). A quick time-release strategy contributes to a greater transfer of NPD experience to NPD performance since the quick adoption of new technologies leads to rapid prototyping that helps to outperform competitors via quick innovation. At the same time, customers may update their expectations and become more critical observants in the case of incremental innovations.

Conversely, we hypothesize that, when firms encounter radical technological changes, the positive effect of breadth of experience disappears if firms quickly release products based on the new technology (Kerin et al., 1992; Mitchell, 1991). With an extensive breadth of experience firms are better aware of which procedures to change, which routines to optimize and how much time all these optimization and alteration procedures require. They should thus, also be better able to explore how to effectively make use of new technologies and introduce new product features that are valued by consumers. In such highly uncertain technological environments, firms progressively accumulate knowledge about how to navigate new technological frontiers. While radically different technologies require drawing on diverse knowledge bases inside a firm, this takes time to be understood and explored thoroughly.

According to Crawford (1992), the commitment of firms to improve new product quality may require time investments and hence, may reduce the speed of the product development process. A quick release of new products makes it impossible to thoroughly apply new complex technologies. Firms simply are not able to leverage on their resources (including experience) quick enough to overcome all uncertainties related to a new technology and skip all essential steps before launching a product (prototyping, testing, collecting market feedback, adjusting product characteristics, etc.). Some inexperienced firms may try to gain a competitive advantage leveraging on the first-mover advantage and neglecting all necessarily steps before a product launch but, in most cases, their efforts will be wasted (Castellion and Markham, 2013; Yang et al., 2015). Statistically, about 40% of new products fail across different industries (Castellion and Markham, 2013) while some scholars show that new product failure may reach even 90% (Gourville, 2006). Hence, new product failure is a common phenomenon that may be caused, among any other factors, by a fast product release.

Based on this evidence, one might expect that fast product release may cancel out a positive effect of breadth of experience. Firms simply will not be able to benefit from it due to insufficient time for application of knowledge and practices used and acquired in the past. Breadth of experience is an advantage that is contingent on time – a slow time-release strategy may help firms with greater breadth of experience (as compared to firms with the low breadth of experience) to improve their NPD performance.[5]

Hypothesis 3. The positive effect of depth of experience on new product quality (in the context of incremental technological changes) is attenuated by the development and market introduction time a firm takes for a new product.

Hypothesis 4. The positive effect of breadth of experience on new product quality (in the context of radical technological changes) is strengthened by the development and market introduction time a firm takes for a new product.

2.4. Methods

2.4.1. Setting

We use the PC video game industry as the empirical setting for our study. The PC gaming industry is a rapidly developing sector of economic activity with a large number of companies. In 2013, there were 1458 PC video game developers globally which produced 2243 PC video games.[6] Worldwide industry sales were estimated at $93 billion in 2013 (ESA, 2015). It is a knowledge-intensive industry where firms compete for better quality and design of software products (video games) based on different generations of hardware technologies.

Within the PC video game industry, we focus on all companies that apply the DirectX platform technology. DirectX facilitates the interaction between hardware components of PC and video games using a Microsoft Windows operation system. Technological changes in PC

[5] In line with the existing literature, we do not hypothesize (but do test) any moderation effects on the positive effect of depth of experience for radical technological changes, and on the positive effect of breadth of experience for incremental technological changes.
[6] According to data published in GameRankings

hardware components (microprocessors, video cards, random access memory, and others) accumulate over time and make preceding versions of DirectX obsolete. Based on the technological changes in PC hardware components, Microsoft introduces, on a continuous but irregular basis, a new generation of DirectX that follows and adjusts to the developments within hardware components. A new generation of DirectX replaces its predecessor and video game developers gradually shift their products to the new version of DirectX or skip a complete version. Products designed for prior versions of DirectX slowly become obsolete (compared to the products oriented towards a new version of DirectX) and disappear from the market. Between 1995 and 2015, 10 main versions of DirectX (regarded as radical technological shifts) and 16 additional iterations (regarded as incremental technological shifts) were released. Table 1 summarizes the evolution of the DirectX technology. According to John (2013), DirectX became a full-value technology after the release of the DirectX 5.0 version. All prior versions were missing some essential technology's components that in a time course were fully assembled in DirectX 5.0. The following progress of DirectX lead to enhancement of the sound and graphical quality of video games to existing technological limits. Each new version of DirectX brings a new portfolio of programming tools and techniques while each new an additional iteration brings incremental improvement of the same version of DirectX. Such significant difference in effects of main versions of DirectX and their iterations makes us split them in 2 groups: (1) incremental and (2) radical (or more radical compared to the previous technology).

The acquisition and use of new programming techniques increase the variation (breadth) and intensity (depth) of a firm's NPD experience. Firms that have developed games using several generations of DirectX have accumulated wider knowledge and skills that might be crucial for the development of products when a new version of DirectX emerges.

Table 1. The main innovations and differences between the most significant versions of DirectX

Version of DirectX	Date of release	Key innovation	Brief description	Additional iterations
DirectX 1.0	30/09/95	Enable playing video games on Windows OS	There were no such applications earlier. The main prior platform was MS-DOS	n/a
DirectX 2.0	01/01/96	Direct3D (D3D)	Technology that allows rendering 3D graphics. DirectX becomes more functional; the main components of a pipeline technology are created	2.0a
DirectX 3.0	15/09/96	Some incremental improvements of the previous version		3.0a, 3.0b
DirectX 4.0		Never released		n/a
DirectX 5.0	04/08/97	Simplification of programming code, no radical changes	The application becomes more user- (developer-) friendly.	5.2
DirectX 6.0	07/08/98	Multitexturing and simplification of programming language	Application of multiple textures on 1 polygon is introduced to improve quality of 3D visualisation	6.1, 6.1a
DirectX 7.0	22/09/99	Hardware-accelerated T&L (Transform and Lightning) technology; new format of textures (.dds)	Redirection of 3D processes specifics from the central processor to the graphic card is applied.	7.0a, 7.1
DirectX 8.0	12/11/00	Shader Model 1.1	Ability to create different visual special effects (e.g., mist, fire, sea surface etc.)	8.0a, 8.1, 8.1a, 8.1b, 8.2
DirectX 9.0	19/12/02	Shader Model 2.0; High Level Shader Language (HLSL); support of Multiple Render Targets (MRT) technology; Multiple-Element Textures (MET) technology	HLSL is a language that allows more efficiently programme shaders; MRT improves multiple rendering; MET enables an application which makes it possible to use 1 or more elements as a single-element texture - that is, as inputs to the pixel shader.	9.0a, 9.0b, 9.0c
DirectX 9.0 c	04/08/04	Shader Model 3.0	Improvement of functionality of Shader Model	
DirectX 10.0	30/11/06	Shader Model 4.0	Improvement of functionality of Shader Model, improvement of HLSL language	10.1
DirectX 11.0	22/10/09	Shader Model 5.0; support of tessellation and redesign of the rendering pipeline	Tessellation means that the quality or dimensions of 3D objects is not constant but changing depending on the distance between the camera and the object	11.1, 11.2

2.4.2. Data

We use video game releases as the unit of analysis. The study relies on data from different independent, public sources (GameRankings; GiantBomb; MobyGames; Statista; VGchartz)[7] covering the period between 1995 and 2014. First, we derived information about the version of DirectX for each video game from the MobyGames dataset. Second, we acquired information about video game 'scores' by GameRanking (which we use to measure new product quality) and link them to the video game developers for each video game. Third, we acquired information about the date of release, the name of video game publisher[8], and the genre for each video game from the VGchartz dataset. Fourth, we derived information about the geographical location of each video game developer from the GiantBomb dataset. Other web-resources were used to check the data and enrich the dataset (LinkedIn, Wikipedia, and IGN). We select new product releases based on the DirectX 5.0 version or higher, because the prior 4 versions (which constitutes about only 10% of the sample) do not entail significant learning efforts from video game developers (John, 2013). In the next step, we excluded observations with a time-release strategy exceeding 50 months (13% of observations), as the large majority of video games is released within the first 18 months after the release of a new DirectX version. Video games that rely on more than 50 months old versions of DirectX are typically not mainstream video games, involve specific genres (e.g., puzzles), and insensitive to changes among versions of DirectX. The lengthy response is often not because of an incapability or unwillingness to use new technologies but results from lower technical video game demands. The net sample size comprised of 940 new video games released by 378 video game developers.

[7] VGchartz (www.vgchartz.com); GameRankings (www.gamerankings.com); GiantBomb (www.giantbomb.com); MobyGames (www.mobygames.com); Statista (www.statista.com).

[8] A publisher's main role is to promote a video game, while the role of developers is to create the product or content. Publishers, sometimes, are vertically integrated into product production and become developers themselves.

Table 2. Descriptive statistics and correlation matrix

	Variables	Min	Max	Mean	Std. Dev	1	2	3	4	5	6	7
1	New product quality	50.27	95.48	74.86	9.87							
2	Depth of experience	0	12	1.13	1.69	.04						
3	Past Depth of experience	0	21	2.02	2.21	.06**	.74***					
4	Breadth of experience	1	9	2.49	1.62	.10***	.39***	.49***				
5	Time-release strategy (in months)	0	59	24.65	17.02	-.13***	.42***	.34***	.15***			
6	Number of reviews	1	89	18.35	14.37	.38***	-.10***	-.03	.06**	-.06**		
7	Age	12	725	146.51	80.90	-.04	.19***	.24***	.46***	.10***	-.09***	
8	Promotional power	1	410	131.29	133.67	.16***	.17***	.24***	.32***	-.07**	.11***	.16***

Notes:
N = 940; * p<.05; ** p<.01; ***p<.001
Dichotomous variables are not reported in the matrix

2.4.3. Measures

Dependent variable:

New product quality. We measure new product quality based on the critical reviews of a large number of video game experts. Critical reviews are combined in aggregated scores and published on the GameRankings web-site ranging from 0 (the lowest) to 100 (the highest).

Following previous studies (e.g., Elliott and Simmons, 2008; Hennig-Thurau et al., 2006), we use expert scores as proxies for new product quality. In contrast to users-based scores, the expert-based scores tend to be more neutral since they do not rely on pricing policy of firms, and, therefore, better represent new product quality.

Independent variables:

To capture depth and breadth of experience, we follow Argote and Miron-Spektor's (2011) and operationalize experience by counting the prior number of products and services that were released. This indicates firm's accumulated experience with the technology.

Depth of experience reflects the extent to which a firm has dealt with a specific technology (one version of DirectX) in the past and is measured as the number of new products (video games) developed using the same technology prior to the release of the focal video game. When a firm adopts a new technology and releases the first new product, depth of experience equals to zero, because the firm has had no prior experience with this technology. When a firm applies the same technology in a third product release, depth of experience equals two, as the firm has had two prior releases based on the same technology. For radical changes, this would, however, imply that depth would always be zero as firms shift to a new technology – despite the differences that may exist regarding firms' accumulated experiences with a prior technology. To capture possible lock-in and inertia effects when firms develop multiple products with the same technology, we operationalize, for the radical changes only, an alternative depth of experience variable and call this **Past Depth of experience**. This alternative measure counts the total number of products developed based on the prior technology when the first product on the new radical technology is released.

Breadth of experience captures a firm's experience with different generations of technologies (versions and iterations of DirectX). It is measured as the number of platform technologies that have been used by a firm to release products using these platform technologies before launching a new product.

Moderators:

Time-release strategy reflects how slow firms apply a new technology (version of DirectX) after its official market release. It is operationalized as the number of months that have elapsed between the release date of a given version of DirectX and the date of the release of the new product based on this technology.

Circumstances firms face: Incremental change and Radical change. These two conditions reflect the type of technological change that firms encounter when developing the focal product. We consider it as an incremental change when a firm shifts between iterations of the same version of DirectX (e.g., when shifting from the DirectX 8.0a version to the version 8.1) (see Table 1). We consider it to be a radical change when firms shift between different versions of DirectX (e.g., shifting from the DirectX 9.0 version to the version 10.0). Following this logic, we split the sample in two subsamples: a sample with products based on technologies that have already been used by firms (incremental shifts) (N=620), and a sample with products based on radically new technologies which have not been used by firms previously (radical shifts) (N=320).

Control variables:

We use a set of control variables to provide a stronger test of our hypotheses. We include both time-variant and time-invariant product-, firm- and market-specific variables.

Sequel. This control variable reflects whether a new video game is an original video game or a continuation (a sequel) of previous video games. Expectations of experts may differ between original releases and sequels, as sequels tend to be compared by experts with their predecessors, while original video games are not. Sequel variable is operationalized as a dummy variable (0=original, 1=sequel).

Genre. Controlling for the genre is important because there are differences in the evaluation of genres. We followed Cennamo and Santalo's (2013) classification of 7 genre types and add one "Others" for games that did not fit any of these genre types.

Number of reviews. We use the number of critic reviews to account for the popularity of video games. The assessment of quality of video games with a low number of reviews may be biased.

Geographical location. The video game developer's location may influence the access to production facilities, media networks, and consumer markets. We allocated the firms that are from 46 countries into 3 dummy categories according to their continental affiliation: North America, Europe and Other countries.

Age. This variable is calculated as the number of months that have elapsed between the developer's incorporation and the date of product release.

Seasonality. To account for seasonality effects, we include a dummy variable to indicate the high season period (November and December) (Binken and Stremersch, 2009). The high number of (top) games released during the Christmas period may influence the assessment of new product quality.

Promotional power. Strong promotional capabilities of video game publishers generally increase product visibility. Such capabilities do not necessarily mean that the visibility impacts reviewers' assessment of video games' quality but may raise attention from a higher number of reviewers as compared to less promoted products. To control for this, we use the total number of published video games by a video game publisher.

2.4.4. Estimation approach

To test our hypotheses, we applied the OLS regression analysis. We ran the analysis in consecutive steps to test for the presence of the main effects and interaction effects, and to evaluate how these effects differ depending on the radicalness of the technological changes that occur in the industry. All models include the same control variables. Before the estimation of the interaction effects, all variables were mean centred.

We also checked for the presence of multicollinearity. The obtained maximum VIF value is 2.09 is far below the critical threshold of 10, suggesting that multicollinearity does not pose a major concern in our study (Hair et al., 2010).

The following models are applied:

First, we estimate for the entire dataset the presence of the direct effects of Breadth and Depth of experience on New product quality (Equation 1):

$$(1)\ Y = a_1 + b_1X1 + c_1X2 + \varepsilon_1$$

Second, we estimated for the entire dataset the moderated effect (Time-release strategy) of Breadth and Depth of experience on New product quality (Equation 2):

$$(2)\ Y = a_2 + d_2Mo + f_2X1Mo + g_2X2Mo + \varepsilon_2$$

Lastly, we applied the same models for incremental and radical data samples.

2.5. Results

Table 3 presents the results. For the entire sample (N=940) and for the incremental innovation sample (N=620), we find evidence that there is a positive effect of Depth of experience (B_{Depth}

$_{\text{of experience}}$ = .92; *p*<.001 and $B_{\text{Depth of experience}}$ = .65; *p*<.026 respectively*)* on New product quality (see Models 1 and 3, Table 3), supporting H1a. Although Depth of experience does not improve New product quality for radical technological changes, we do not find empirical support that it negatively affects New product quality under such shifts ($B_{\text{Depth of experience}}$ = .27; *p* = .356; [Model 5, Table 3]), thereby rejecting H1b. Although not hypothesized, we find that the main effect of Time-release strategy on New product quality is negative ($B_{\text{Time-release strategy}}$ = -.13, *p* = .024; [Model 1, Table 3]), implying that faster development times lead to higher quality products.

As H2a postulates, we find that Breadth of experience does not impact New product quality when firms are confronted with incremental technological changes (($B_{\text{Breadth of experience}}$ = -.01; *p* = .978; [Model 3; Table 3]). We reject H2b as we do not find a positive effect of Breadth of experience on New product quality when firms are confronted with radical technological changes ($B_{\text{Breadth of experience}}$ = -.47; *p* = .317; [Model 5; Table 3]).

As proposed in H3, we find that the positive effect of Depth of experience decreases when firms take longer for a technology adoption after a new technology is released. Model 2 shows –for the full dataset– a statistically significant negative interaction effect on New product quality ($B_{\text{Depth of experience×Time-release strategy}}$ = -.04; *p* = .014). This implies that, other things being equal, New product quality depreciates by .04 points for each additional extra month before release. The interaction term is, however, only significant for the full dataset, but not for the separate models of incremental and radical changes (see Models 4 and 6; Table 3).

As stated in Hypothesis 4, the effect of Breadth of experience on New product quality is stronger for those that take more time to release their new products. Model 2 –for the full dataset– shows a statistically significant positive interaction effect ($B_{\text{Breadth of experience×Time-release strategy}}$ = .06; *p*<.001). When looking at the coefficients for the interaction effect for incremental ($B_{\text{Breadth of experience×Time-release strategy}}$ = .06; *p*<.001; [Model 4; Table 3]) and radical ($B_{\text{Breadth of}}$

$_{\text{experience×Time-release strategy}}$ = .09; p=.003; [Model 6; Table 3) changes, we see that the interaction effect of Breadth of experience and Time-release strategy seems more pronounced for radical technological changes.

To facilitate the interpretation, we plot two graphs for each interaction effect (see Figures 3 and 4) using the results from Model 2. To highlight how the impact of Depth and Breadth varies according to different Time-release strategies, we display the slopes for low (Mean -1SD), medium (Mean), and high (Mean +1SD) levels of time required before release.

Figure 3 shows that firms benefit more strongly from Depth of experience when they shorten their Time-release strategy. When firms succeed to develop video games within the first 8 months after the DirectX release, they can significantly increase the New product quality. At 42 months of delay the positive effect of Depth of experience no longer exists and becomes a burden that leads to lower New product quality. Opposite moderation effects occur regarding the influence of Breadth of experience in conjunction with time-release strategy (Figure 4). Firms benefit more strongly from Breadth of experience when they take more time to experiment and release their new products. The benefits of late release only occur when Breadth of experience is two or greater (i.e., firms have launched products in the past using at least two radically different technologies). When the level of Breadth of experience is lower than two, late release causes a negative effect on New product quality.

The control variables show expected relationships, and display consistent effects across the 6 models. The number of reviews has a positively significant effect on New product quality ($B_{\text{Number of reviews}}$ = .28; p<.001; Model 2). Sequels have a significantly higher New product quality than original video games (B_{Sequel} = 3.26; p<.001; Model 2). The other control variables have no significant effect.

Table 3. Regression results for New product quality

Predictors	All observations		Observations for *incremental* changes		Observations for *radical* changes (Past Depth of experience)	
	Direct effects Model 1	**Interaction effects Model 2**	**Direct effects Model 3**	**Interaction effects Model 4**	**Direct effects Model 5**	**Interaction effects Model 6**
Constant	**67.64*** (1.15)**	**67.38*** (1.15)**	**67.97*** (1.50)**	**67.60*** **	**64.90*** (1.96)**	**64.70*** (1.95)**
Depth of experience	**.92*** (.25)**	**1.00*** (.30)**	**.65* (.29)**	**.59† (.35)**	.27 (.29)	.19 (.30)
Breadth of experience	-.07 (.23)	-.13 (.22)	-.01 (.27)	-.17 (.28)	-.47 (.47)	-.06 (.48)
Time-release strategy	**-.13*** (.02)**	**-.12*** (.02)**	**-.13*** (.03)**	**-.13*** (.03)**	**-.13** (.04)**	-.06 (.05)
Depth ×Time-release strategy		**-.04* (.02)**		-.02 (.02)		.01 (.02)
Breadth ×Time-release strategy		**.06*** (.02)**		**.06*** (.02)**		**.09** (.03)**
Sequel	**3.18*** (.61)**	**3.26*** (.61)**	**3.31*** (.80)**	**3.43*** (.80)**	**2.49** (.95)**	**2.60** (.94)**
Number of reviews	**.27*** (.02)**	**.28*** (.02)**	**.24*** (.03)**	**.24*** (.03)**	**.35*** (.04)**	**.37*** (.04)**
Age	-.01 (.00)	-.00 (.00)	.00 (.01)	.00 (.01)	-.01† (.01)	-.01† (.01)
Seasonality	-.25 (.62)	-.16 (.61)	.07 (.80)	.21 (.80)	-.54 (.96)	-.29 (.95)
Promotional power	.00 (.00)	.00† (.00)	.00 (.00)	.00 (.00)	**.01* (.00)**	**.01* (.00)**
Dummies Genres included	YES	YES	YES	YES	YES	YES
Dummies Geographical location included	YES	YES	YES	YES	YES	YES
R Square	.231	.247	.189	.204	.362	.381
R Square adjusted	.218	.232	.168	.180	.329	.344
F change	10.236***[a]	9.456***	6.227***[a]	5.296**	3.394*	4.552*
N	940	940	620	620	320	320

Notes:
†p<.1; * p<.05; ** p<.01; *** p<.001
Unstandardized coefficients are reported with standard errors in parentheses. Control variables are not reported (but are used in the tests). The detailed results are in Annex 1.
a - the model is compared with a null model (when the test is run only with the control variables)

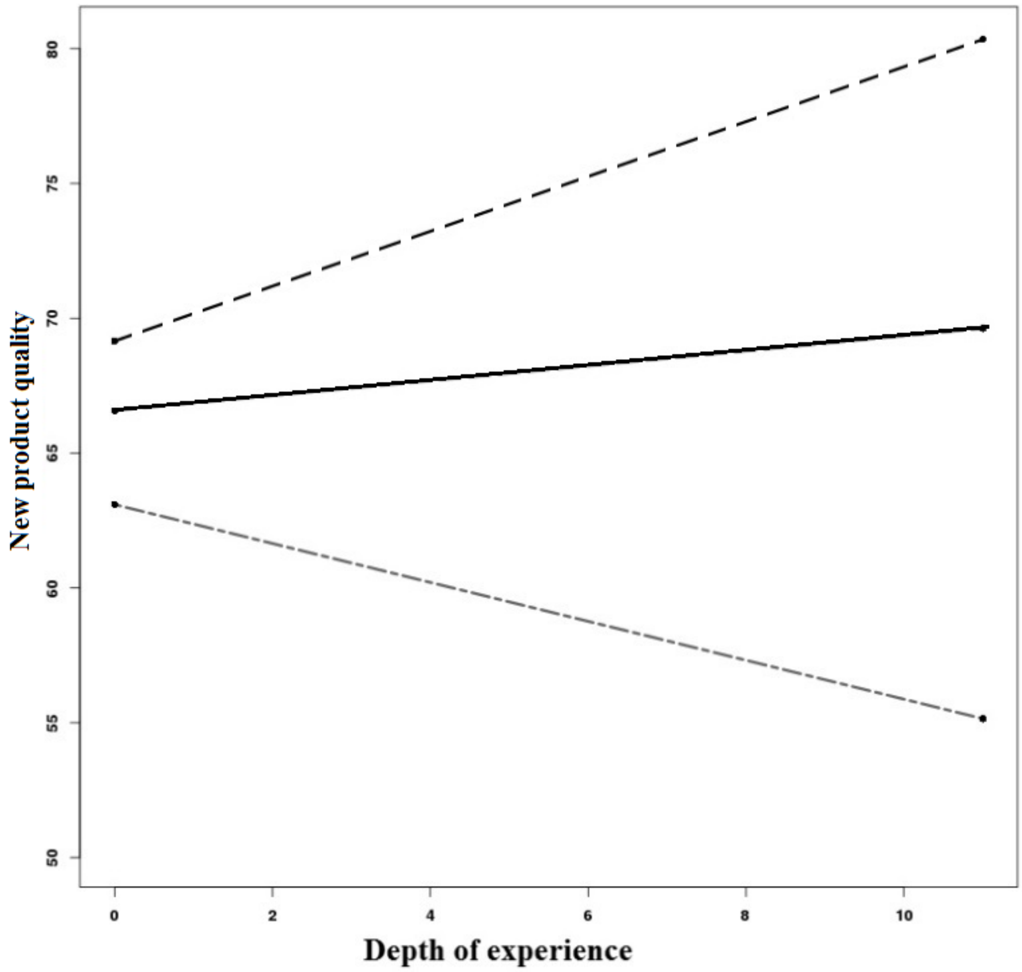

Figure 3. Effect of depth of experience on new product quality for varying time-release strategies

Dashed line - Time-release strategy of 8 months after the technological change (-1SD)
Solid line - Time-release strategy of 25 months after the technological change (Mean)
Dash-dot line - Time-release strategy of 42 months after the technological change (+1SD)

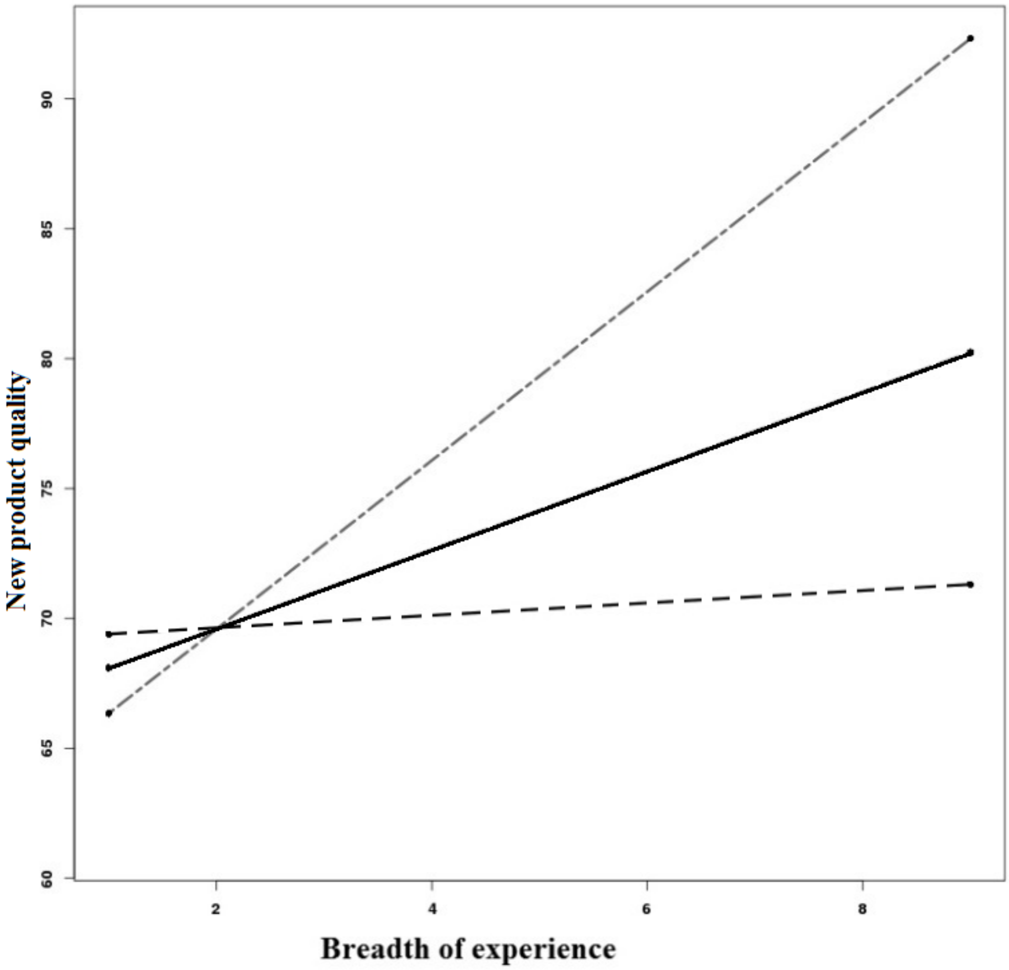

Figure 4. Effect of breadth of experience on new product quality for varying time-release strategies

Dashed line - Time-release strategy of 8 months after the technological change (-1SD)
Solid line - Time-release strategy of 25 months after the technological change (Mean)
Dash-dot line - Time-release strategy of 42 months after the technological change (+1SD)

2.5.1. Robustness checks

To check how sensitive our results are with respect to the methodological choices we have made, we conducted several additional checks. First, we estimated two models with an alternative specification of Depth of experience (Past Depth of experience) on the sample with all observations and the sub-sample with observations that reflect only incremental changes. This new variable is applied to reflect the impact of past knowledge (experience) and potential lock-in or inertia effects, when firms are confronted with a radical change (and to avoid that our Depth of experience equals zero). The obtained results are highly similar to those from the main models (see Model 7 and 8, in Table 4).

Secondly, we mean-centered New product quality separately for each year and ran the analysis with the new specification of the variable. In this way we consider the relative performance of the video game within a year and can investigate the results if we account for unobserved annual changes in the scoring of video games. The results are comparable; the only difference was a decrease in the significance of the direct effect of Time-release strategy (Model 9).

Thirdly, we re-operationalized Depth of experience and Breadth of experience. While the initial values of these variables were calculated using the information about versions of DirectX that firms report, we altered the values based on information taken from the MobyGames database. The new values are based on the general information about the up-to-date version of DirectX available in the industry when the products (video games) have been released. A firm could release a video game applying the DirectX 6.0 technology while the DirectX 7.0 one was on the market. In this case, for operationalization of initial values of Depth of experience and Breadth of experience, we consider DirectX 6.0 as a reference one. In the case of re-operationalized variables, we consider DirectX 7.0 as a reference one assuming that firms could have indirect access to the information about new versions of DirectX (since technology was already on the market) and could enrich their NPD experience even if they did not adopt those new versions of DirectX in their products. The analysis shows similar results (Model 10; Table 4). However, the significance of the direct effect of Depth of experience is weaker due to lower variability.

Table 4. Regression results robustness checks

Predictors	All observations (Past Depth of experience)	Observations for incremental changes (Past Depth of experience)	Mean-centred New product quality	Re-operationalized IV according to DirectX release	50% of all observations
	Interaction effects Model 7	**Interaction effects Model 8**	**Interaction effects Model 9**	**Interaction effects Model 10**	**Interaction effects Model 11**
Constant	**67.16*** (1.17)**	**67.58*** (1.51)**	**-3.86*** (1.16)**	**66.64*** (1.16)**	**69.17*** (1.62)**
Depth of experience	.13 (.20)	.08 (.26)	**.93** (.30)**	.14 (.21)	**1.27*** (.38)**
Breadth of experience	-.06 (.23)	-.17 (.30)	.01 (.23)	.07 (.15)	.10 (.30)
Time-release strategy	**-.10*** (.02)**	**-.13*** (.03)**	**-.05* (.02)**	**-.08*** (.02)**	**-.12*** (.03)**
Depth ×Time-release strategy	**.01 (.01)**	**.01 (.01)**	**-.04* (.02)**	**-.02† (.01)**	**-.04 (.02)**
Breadth ×Time-release strategy	**.05*** (.02)**	**.05** (.02)**	**.07*** (.02)**	**.05*** (.01)**	**.06** (.02)**
Sequel	**3.55*** (.61)**	**3.61*** (.80)**	**3.41*** (.61)**	**3.76*** (.60)**	**3.09*** (.83)**
Number of reviews	**.27*** (.02)**	**.24*** (.03)**	**.28*** (.02)**	**.28*** (.02)**	**.27*** (.03)**
Age	-.01 (.00)	.00 (.01)	-.00 (.00)	-.00 (.00)	-.01 (.01)
Seasonality	-.12 (.62)	.31 (.80)	-.07 (.62)	.09 (.62)	-1.71* (.84)
Promotional power	.01 (.00)	.00 (.00)	.00 (.00)	.00 (.00)	.01 (.00)
Dummies Genres included	YES	YES	YES	YES	YES
Dummies Geographical location included	YES	YES	YES	YES	YES
R Square	.238	.201	.237	.243	.289
R Square adjusted	.223	.177	.222	.228	.262
N	940	620	940	940	470

Notes:
† p<.1; * p<.05; ** p<.01; *** p<.001
Unstandardized coefficients are reported with standard errors in parentheses.
Control variables are not reported (but are used in the test)

Table 5. Regression results robustness checks

Predictors	**All observations (Time-release strategy max. 8 months)**	**All observations (Time-release strategy max. 25 months)**	**All observations (Time-release strategy max. 42 months)**	**All observations (Time-release strategy max. 60 months)**
	Interaction effects Model 12	**Interaction effects Model 13**	**Interaction effects Model 14**	**Interaction effects Model 15**
Constant	**59.93*** (6.04)**	**67.77*** (1.09)**	**66.87*** (1.19)**	**67.62*** (1.09)**
Depth of experience	**-2.52 (5.65)**	**.85 (.58)**	**1.10** (.31)**	**.80** (.28)**
Breadth of experience	2.70 (2.70)	.18 (.39)	-.21 (.23)	-.15 (.22)
Time-release strategy	**-.55† (.32)**	**-.15** (.05)**	**-.14* (.03)**	**-.07*** (.02)**
Depth ×Time-release strategy	**-.29 (.33)**	**-.07 (.05)**	**-.05* (.02)**	**-.03* (.01)**
Breadth ×Time-release strategy	**.26 (.19)**	**.09** (.04)**	**.05** (.02)**	**.05*** (.01)**
Sequel	**2.35† (1.26)**	**2.96*** (.73)**	**3.13*** (.63)**	**3.08*** (.56)**
Number of reviews	**.34*** (.05)**	**.28*** (.03)**	**.29*** (.02)**	**.28*** (.02)**
Age	-.01 (.01)	-.01 (.01)	-.00 (.00)	-.00 (.00)
Seasonality	-.58 (1.40)	-.33 (.75)	-.11 (.63)	-.05 (.57)
Promotional power	.01** (.01)	.01* (.00)	.01† (.00)	.00 (.00)
Dummies Genres included	YES	YES	YES	YES
Dummies Geographical location included	YES	YES	YES	YES
R Square	.255	.253	.244	.236
R Square adjusted	.190	.230	.228	.223
N	225	600	877	1082

Notes:
† p<.1; * p<.05; ** p<.01; *** p<.001
Unstandardized coefficients are reported with standard errors in parentheses.
Control variables are not reported (but are used in the tests)

Fourthly, to check whether the data are sensitive to changes in the number of observations, we randomly excluded 50% of the observations and re-ran the analysis (split-sample test). The results are consistent with the results of the main sample (Model 11; Table 4). All additional checks suggest that our findings are robust using alternative specifications, and for different (sub)samples.

Finally, we run 4 analyses for samples with different limits of the time-release strategy: (1) for 8 months (the mean value minus 1 standard deviation); (2) for 25 months (the mean value of Time-release strategy); (3) for 42 months (the mean value plus 1 standard deviation); and (4) for 60 months (a maximum number of months when firms still benefit from their experience according to Argote (1999)). The results of these sensitivity checks are presented in Table 5 (Models 12-15). All specifications but one (for Time-release strategy of 8 months) show similar results as those in the main specification (Models Table 5). The inconsistent results of Model 12 in Table 5 indirectly support Hypothesis 4 by showing that a quick Time-release strategy cancels the effect of Breadth of experience. In addition, we ran the analysis where we allowed the values for Time-release strategy reach up to 72 months and discover that the interaction effect between Depth of experience and Time-release strategy becomes insignificant. This is consistent with the findings of Argote (1999), who finds that firms do not benefit from knowledge older than 60 months.

2.6. Discussion and Conclusion

The study discerns between breadth and depth of experience and reveals that the degree to which firms may learn effectively from their NPD experience and improve their NPD performance – in terms of new product quality – depends on their time-release strategies.

Our results indicate that depth of experience is a valuable asset particularly when firms face incremental technological changes. These findings imply that firms can improve product quality, when they successfully introduce products using the same technology through the development of routinized activities that allow them to easily cope with minor changes in a certain technology or technological trajectory. The findings are in line with previous research and show a positive impact on product quality of firms' routinized activities or operational capabilities which firms gain with NPD experience (Ambrosini et al., 2009; Eisenhardt and Martin, 2000; Nieves and Haller, 2014). In the context of densely competitive but relatively stable technological environment, longer development time hurts firm's new product quality, as knowledge devaluates fast (Laursen and Salter, 2006). Firms thus have to quickly apply lessons given by depth of experience in order to improve performance. When this knowledge is not timely exploited, such lessons may be used at the wrong time, or in the wrong place leading to errors (Laursen and Salter, 2006). Our results show that knowledge based on depth of experience depreciates fast which extends studies about fast knowledge devaluation and benefits of being first-mover (Argote, 1999; Lee, 2009).

Breadth of experience does not improve firms' NPD performance directly, but it can improve new product quality when firms do not rush to develop a new product based on a new technological platform. Breadth of experience seems to yield valuable lessons for the development of higher quality products only when firms that have experienced previous radical shifts experiment sufficiently, and do not release their products too early. Our results show that the transfer of breadth of experience appears not only to be valuable for radical changes, but also for incremental changes. These results challenge the assumption that the impact of NPD experience as a resource facilitates first-mover advantage, as suggested by previous research (Lieberman, 1989; Schilling, 2002; Suarez and Lanzolla, 2007). Our study shows that firms with extensive breadth of experience benefit from late-mover advantages, and that being a first-mover can be harmful.

With these findings, our study contributes to the organization learning theory and NPD literature. In response to Argote and Miron-Spector's (2011) call to investigate the important role of firms' knowledge as a function of experience, we provide empirical evidence that firms, indeed, can learn from NPD experience and that this influences firms' performance. By partitioning NPD experience into depth and breadth of experience, we identify what type of NPD experience is needed for improving new product quality in incremental and radical technological environments.

Against our expectations, breadth of experience does not improve directly firms' NPD performance when confronted with radical changes. The finding of the insignificant direct effect may indicate that learning from previous radical shifts may be difficult, and do not automatically lead to a greater ability to develop high quality products. Its effect is only noticeable in conjunction with the (right) time-release strategy, regardless whether technological changes are radical or incremental. This finding highlights the mechanism through which breadth of experience becomes useful for firms to improve their NPD performance. In particular, it shows that firms can only benefit from their accumulated experiences with radical technologies by choosing an appropriate time-release strategy for their new products. Firms with extensive breadth of experience should take sufficient time to the release a new product based on the new technology since they are then able to effectively learn from the failures of early entrants, and they know how to effectively change organizational routines and experiment with the technology to improve new product quality. This impact of breadth of experience is particularly pronounced for the uncertain context of radical technological changes.

By providing evidence regarding the interaction between NPD experience and the time-release strategy, our study also contributes to the first-mover (dis)advantage theory (Lieberman and Montgomery, 1988; Rasmusen and Yoon, 2012; Rodríguez-Pinto et al., 2011). We show that superior product quality in the context of radical technological changes is achieved not via instant adoption of a new technology and release of a new product, but via learning how to deal with a new technology (Ingram, 2002) and elaborative experimentation and gradual utilization of a new technology (e.g., Bingham and Davis, 2012). All these actions require time and their success depends on the past experience with the implementation of radically new technologies in the production process.

Our study also shows that there is a negative statistically significant direct effect of time-release strategy on new product quality, suggesting a first-mover advantage. The opposed effects in the direct impact of time-release strategy, on the one hand, and the interaction effect of breadth of experience with time-release strategy, on the other hand, allows concluding that experienced and inexperienced firms need to follow different time-release strategies. Given that firms with extensive breadth of experience benefit more from delaying, one might conclude that newcomers would definitely lose in competition with incumbents if they try to follow the same time-release strategy. Such results contradict the literature that insist on advantages of risky and dynamic newcomers over risk-averse and inflexible incumbents when a radical change occurs. The lack of NPD experience will not allow newcomers to apply the same routines for product development as incumbents do during a radical technological change. This also involves a learning process when a new technology emerges (Dahlin and Behrens, 2005; Eisenhardt and Martin, 2000). Experienced firms, which understand the complexity of new radical technologies, maty afford spending more time on learning and experimentation in order to achieve a higher new product quality (a strategy of waiting). In contrast, less experienced firms like startups that lack NPD experience, act opportunistically and adopt a new technology faster, hoping to benefit from its higher performance compared to the prior technology and to gain from the first-mover advantage.

Our results also support the claim of Argote (1999) that knowledge depreciates over time and firms do not benefit from the acquired knowledge after 5 years. In particular, we find that NPD experience has a significantly positive influence within the first 6 years following the emergence of a new technology, but after 6 years the effect disappears. However, in contrast to Argote (1999) and other studies showing that recent NPD experience is more valuable for firms than more distant past experience (Argote et al., 1990; Argote and Miron-Spector, 2011; Benkard, 2000), we only find depreciation of the positive effect of NPD experience acquired via encountering incremental technological changes (extensive exploitation of one certain technology), as opposed to encountering radical changes.

Apart from providing new empirical evidence on the impact of NPD experience on new product performance, this study also extends existing literature by (1) proposing a new way of conceptualization of NPD experience with regard to intensity and the nature of technological changes (regimes); (2) uncovering an asymmetric influence of depth and breadth of experience that opens a new avenue for studying the effects of knowledge gained via encounters with incremental and radical technologies on firms performance; (3) revealing the importance of taking into account the effect of time-release strategy while investigating the relationship between NPD experience and new product performance.

The results also lead to several managerial implications and suggest that managers should acknowledge the relative strengths (i.e. accumulated breadth and depth of experience) when reacting on new radical and incremental technological changes, as well as those of their competitors. Incumbent firms may benefit more from an emerging technology than newcomers. While age may be considered to work negatively (inertia) in the adoption of radically different technologies, this study shows that age – when combined with greater breadth of expertise – may be a strength rather than a liability. Taking sufficient time to experiment and learn from market mistakes by early mover may lead to the development of superior products. This evidence may help firms understand how flexible they are with respect to time-release strategy, and whether the aim to quickly develop, ahead of the competition (in case of incremental changes), or thoroughly experiment and learn from competitor offerings (in case of radical changes) is beneficial. The results may also assure practitioners (and shareholders) of experienced developers that the time spent on learning and mastering a new radical technology could bring more benefits than fast integration of the new technology in products. The results also have implications for a shift in release strategies when firms mature; startups do well to gain sufficient depth of experience, and quickly release products, while older firms do well to shift more toward slow releases for both radical and incremental technologies.

There are also some limitations in this study that stimulate further research. First of all, the study is based on one industry. While the results of the study can be applicable to other software industries, their applicability to traditional manufacturing industries may be less straightforward. Some of such traditional industries may be based on less knowledge intensive products and technological changes may occur unfrequently there. Hence, the effects from depth and breadth of experience and time-release strategy may differ due to a slow pace of technological improvements within such industries. Another study based on a less knowledge intensive industry might be needed to obtain the general picture of the role of firms' NPD experience in firms' NPD performance.

Secondly, studying the effect of NPD experience on new product quality sheds light only on one dimension of firms' experience. This dimension addresses technological issues related to firms' R&D activities while other issues are not addressed by this type of experience. It would also be interesting to investigate the effects of diverse types of experience (e.g., market; alliances; marketing; social changes and other business-related types) on new product quality. Scholars could analyze what types of the experience are the most valuable for firms, what types of the experience can be harmful under certain conditions, and what helps to avoid or lessen the negative impact of such experiences. Considering the knowledge spillover effect, it would be worth studying how the turnover of different categories of employees affects NPD performance.

Thirdly, in our study NPD performance was measured by means of product quality derived from product reviews. Further research could assess whether similar effects occur using other financial (product unit sales, revenues, market share and profit margins) or artistic (awards, critical acclaim) performance measures are used.

All this would allow developing a robust theoretical model of the role of multidimensional firms' experience on firm's NPD performance. Such understanding is valuable in terms of conceptualization of the experience not only for academics in business related studies but also for practitioners that want to know how different dimensions of experience impacts their performance. We hope to inspire researchers to address these questions in future research.